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The η Chamaeleontis cluster: recent results

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Abstract. The η Chamaeleontis star cluster is one of the most important nearby groupings of pre-main sequence (PMS) stars. With accurately known distance, compact structure and highly-coeval intermediate-aged population, the η Cha cluster is an important laboratory for enhancing our understanding of all PMS star evolutionary issues. In this paper, recent results concerning the stellar population are discussed including the discovery of a rare example of a $\sim$ 10 Myr-old Classical T Tauri (CTT) star. This and other objects point to an X-ray-faint late-type population residing amongst the *ROSAT*-detected membership.

1. Characterization of a new star cluster

The η Chamaeleontis star cluster is a recently-discovered group of $\sim$ 10 Myr-old PMS stars at a distance of only 97 pc (Mamajek, Lawson & Feigelson 1999a). The cluster was discovered following a *ROSAT* HRI pointing at a compact group of 4 *ROSAT* All-Sky Survey (RASS) sources. The 4 RASS sources were recovered along with 8 additional sources. Spectroscopy of the optical counterparts of these sources (denoted as RECX stars by Mamajek et al. 1999a) showed 10 of these stars had the optical characteristics of late-type Weak-lined T Tauri (WTT) stars, as evidenced by optical activity (Hα emission with equivalent widths $EW = 1 - 20$ Å) and enhanced λ6708 Li I absorption ($EW = 0.4 - 0.6$ Å). The optical counterparts of the other two X-ray sources were the bright B8 star η Cha and the A7 + A8 binary RS Cha.

The PMS nature of the RECX stars was confirmed via *Hipparcos* and Tycho astrometry. *Hipparcos* parallaxes and proper motions for η Cha and RS Cha gave a weighted parallax for the two stars of $\pi = 10.3 \pm 0.3$ mas (distance $d = 97 \pm 3$ pc) and proper motions (μ_α cos δ, $\mu_\delta = -30$, $+28$ mas yr^{-1}). Half of the late-type RECX stars (RECX 1, 9, 10, 11 and 12) and the X-ray-quiet A5 star HD 75505 can be related to η Cha and RS Cha via common parallax and/or proper motions (Mamajek et al. 1999a, Mamajek, Lawson & Feigelson 2000, Lawson et al. 2001a). Preliminary placement of the RECX stars on the HR diagram suggested a common age of $\sim$ 10 Myr (Mamajek et al. 1999a).

Published work to date on the η Cha cluster includes announcement of its discovery and analysis of spectroscopy of the RECX stars (Mamajek et al. 1999a), a search for microwave radio emission from the RECX stars (Mamajek, Lawson & Feigelson 1999b), consideration of the kinematic origin of the cluster and detailed analysis of the *ROSAT* X-ray light curves (Mamajek et al. 2000;

also see Mamajek & Feigelson, these proceedings), and long-term photometric study of the late-type stars for rotation period analysis and accurate HR diagram placement (Lawson et al. 2001a). In addition, Lawson & Feigelson (2001) compared the cluster HR diagram to several contemporary sets of PMS evolutionary tracks, concluding that most models failed to achieve coevality across the observed range of stellar spectral types.

In this paper, some of the more recent work and forthcoming detailed studies of the cluster's stellar population are highlighted.

2. Recent work and new results

2.1. Photometric study of the RECX stars

Multi-epoch V-band photometric monitoring during 1999 and 2000 of the 10 late-type RECX stars showed that all were variable in one or both years, with the light variations ascribed to rotational modulation by cool starspots (Lawson et al. 2001a). Rotation periods ranging from $1.3 - 20$ d were observed in the RECX stars, with the observed periods being generally consistent from 1999 to 2000. Some stars showed significant changes in the light curve amplitude between the two observing seasons, as would be expected from the evolution of the obscuring spots over the course of a year.

Calibrated *VRI* photometry allowed us to better place the RECX stars on the HR diagram and to infer intrinsic properties such as radius and temperature. Surprisingly, comparison between the rotational and X-ray properties of these objects indicated the 'saturation' level observed across many samples of PMS stars, log $(L_{\rm X}/L_{\rm bol}) \approx -3$, persists across all rotation periods in the RECX stars. This unexpected finding strongly hints that the dynamo mechanism may be inadequate in explaining X-ray emission in young stars!

2.2. η Cha – coeval cluster

HR diagram placement of the RECX stars (Lawson at al. 2001a) showed a several Myr scatter in apparent age that was ascribed significantly to unresolved binaries. In particular, two stars (RECX 9 and 12) appeared elevated by a factor of 2 in luminosity above other RECX stars of similar spectral type, and there was nearly a factor of 2 scatter in the luminosities of the mid-K stars (RECX 1, 7 and 11). The location of RECX 9 and 12 was interpreted as representing the locus of near-equal-mass binaries in the sample.

Recently, Koehler (these proceedings) observed the RECX stars using the ADONIS adaptive optics system on the ESO 3.6-m telescope and found RECX 1 and 9 to be binaries with ≈ 0.2 arcsec separation (20 AU projected distance). The K-band brightness ratios were $\approx$ 1:1 (RECX 1) and 2:1 (RECX 9). Lawson et al. (2001a) found RECX 12 to be multi-periodic with 1.3 and 8.6 d periods present in the light curve during both 1999 and 2000. Since a several Myr-old close binary can be tidally-locked, then one of these periods might also be the orbital period. If this interpretation is correct, then the inferred separation of the RECX 12 binary is < 0.25 AU. When the known and probable binaries are accounted-for, cluster members appear highly coeval to ± 1 Myr depending on the adopted PMS evolutionary tracks.

Lawson & Feigelson (2001) compared the cluster HR diagram to several contemporary grids of PMS evolutionary tracks, and found factors of $2-4$ disagreement in the inferred age and mass of individual cluster members. An important test for the PMS models is the RS Cha binary. Current models gave correct masses for the binary components (compared to dynamical masses), but the inferred age of the binary system differed by a factor of 2. The models of Seiss, Dufour & Forestini (2000) give more self-consistent ages across the cluster HR diagram and color-mag diagram than the other models examined.

With known members ranging from spectral type B8 to M4, and straddling a factor > 4 in temperature, > 10 in mass and > 1500 in luminosity, the η Cha cluster is thus a critical and difficult test for any PMS evolutionary model.

2.3. New members - a CTT star in the η Cha cluster

Compared to most field stars of similar color (or temperature), the η Cha stars are elevated in magnitude (or luminosity) in the color-mag (or HR) diagram due to a combination of youth, proximity, and low interstellar reddening towards the cluster [Westin (1985) found $E(b-y) = -0.004$ for η Cha]. Also, the late-type RECX stars form a predicatable sequence in the colour-mag (or HR) diagram due to their coevality (Lawson et al. 2001a) and the cluster is compact (~ 1 pc extent) indicating there will be a minimal ($\sim 1\%$) geometric contribution to the photometry.

These favourable properties can be used to photometrically-select new candidate cluster members. Follow-up spectroscopic study can then be conducted for signs of stellar youth, most importantly the presence of enhanced lithium. Thus new members of the η Cha cluster can be found irrespective of their X-ray properties and without prior knowledge of their distances or proper motions. (X-ray and parallax/proper motions have been used to find members of other nearby associations such as the TW Hya association; see e.g. Webb et al. 1999).

A limited-area search near the central regions of the cluster has been made by Lawson et al. (2001b), who found several candidate members with a similar locus in the color-mag diagram as the known members, of which two were subsequently identified as optically-active, lithium-rich low-mass objects. The most significant of these is ECHA J0843.3–7905 (= *IRAS* F08450–7854; Moshir et al. 1989), a $V = 14.0$ CTT star with an optical spectrum dominated by strong Balmer and Ca II emission. At a distance of 97 pc, the star is probably the second-closest known CTT star to Earth after TW Hya (if the CTT population of the MBM12 cloud is > 100 pc distant as suggested by Luhman, these proceedings) and another rare example of an 'old' CTT star. Compared to TW Hya, ECHA J0843.3–7905 is of slightly later spectral type (M2, compared to K7) and may have slightly lower Hα activity ($EW = -110$ Å, compared to -140 Å) although it has currently unknown Hα variability. Like other CTT stars ECHA J0843.3–7905 has a strong infrared excess, with a $V-[12]$ excess of ~ 5 mag, and shows high optical ($\Delta V = 0.6$ mag) photometric variability.

The other new cluster member is the M4 WTT star ECHA J0841.5–7853, which is currently the lowest mass ($\approx 0.2\ M_\odot$) and optically faintest primary ($V = 17.1$) known in the cluster. Neither of these stars were detected by *ROSAT* HRI (Mamajek et al. 1999a, 2000), indicating we are beginning to detect a population of X-ray-faint low-mass cluster members with $\log L_{\rm X} < 28.5\ {\rm erg\,s^{-1}}$;

the flux of the weakest *ROSAT* HRI source, RECX 9. We are also studying a number of other low-mass cluster candidates.

2.4. The disk fraction for η Cha stars

Lyo et al. (2001) will present L-band photometry of the η Cha stars obtained during the 1999 southern winter with the SPIREX telescope sited at the South Pole. Two of the η Cha stars show strong L-band excesses; the CTT star ECHA J0843.3–7905 discussed above, and RECX 11. The latter star was identified by Mamajek et al. (2000) as a transition class II/III young stellar object between the CTT and WTT phases. RECX 11 has only moderate optical activity (Hα $EW = -7$ Å) but is listed in the *IRAS* Faint Source Catalogue (= *IRAS* F0847–7848). Other RECX stars show weaker L-band excesses.

3. The significance of the η Cha cluster

The η Cha cluster is a nearby ($d = 97$ pc), compact (extent ~ 1 pc), unreddened, coeval intermediate-aged (~ 10 Myr-old) grouping of PMS stars. This unusual combination of characteristics makes it an ideal laboratory for the study of all PMS evolutionary issues, e.g. study of rotational evolution, disk dissipation and planet formation, magnetic activity evolution, the nature of PMS brown dwarfs expected to accompany the stellar population, the dynamical evolution of young clusters, etc. The cluster has already proven to be a demanding calibrator for PMS evolutionary models.

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